N AND P EDGE-OF-FIELD LOSSES FROM POULTRY LITTER APPLICATIONS

R.W. Vervoort, D.E. Radcliffe, M.L. Cabrera[1], M. Latimore Jr.[2]

AUTHOR: [1] Graduate student, Associate Professor and Associate Professor, Department of Crop and Soil Sciences, University of Georgia, Athens, Ga 30602. [2] Associate Professor, Plant Science Department, Ft. Valley State University, Ft. Valley, Ga 31030.

REFERENCE: Proceedings of the 1997 Georgia Water Resources Conference, held March 20 - 22, 1997, at the University of Georgia, Kathryn J. Hatcher, Editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. Excess application of poultry litter may cause pollution of surface and ground water with Nitrogen (N) and Phosphorus (P). Composting poultry litter could reduce the risk of pollution by creating more stable organic components. Three rates of poultry litter and compost (10 Mg ha^{-1} litter, 20 Mg ha^{-1} litter and 10 Mg ha^{-1} litter combined with 50 Mg ha^{-1} compost) to three watersheds under pasture. The watersheds were monitored for surface and subsurface flow. Nitrate concentrations in subsurface flow did not exceed the U.S. Environmental Protection Agency drinking water standard of 10 mg L^{-1}. Soluble P concentrations in runoff were high, reaching a maximum of 8.5 mg L^{-1} under the compost treatment. Concentrations of P in soil in the top 15 cm increased dramatically under the compost treatment which creates a high potential for future runoff of P. Total losses of N and P were low, mainly due to few runoff and subsurface events.

INTRODUCTION

In 1993, Georgia ranked second in the U.S. in total broiler production. The total number of birds raised was estimated at almost 960 million and the total value of production at 1.5 billion dollars (Georgia Agricultural Statistics Service, 1994). Significant quantities of waste are generated during production. Perkins et al. (1964) estimated that 1000 broilers produce about 1460 kg of litter (bedding material consisting of mainly sawdust and woodshavings in Georgia) in their 10 week life cycle, which means Georgia produced almost 1.4 billion kg of litter in 1993. During poultry production, the manure from the broilers is mixed with the bedding material, so the result is a mixture of which the nutrient value can differ. These wastes pose a risk to the environment which is magnified by the generally concentrated production of poultry. Pollution of ground and surface water by nitrogen (N) and phosphorus (P) are attributed to excessive application of animal wastes. Inorganic N and P are linked to eutrophication of lakes and nitrate-N in drinking water may be harmful to humans and animals. Composting poultry litter may limit environmental contamination, due to more stable organic compounds.

Nitrate-N is generally considered to be highly mobile, losses are generally through subsurface flow and deep leaching to the groundwater. Ammonium-N and P are generally considered to have low mobility, being strongly adsorbed. Losses are generally related to runoff and erosion (Khaleel et al, 1980), but prolonged application of animal wastes on sandy soils could cause leaching of phosphorus (de Haan and van der Zee, 1994). This research studies the N and P losses in runoff and subsurface flow from pasture-applied poultry litter and composted poultry litter.

MATERIAL AND METHODS

Three 0.45 ha watersheds at Ft. Valley in the Flint river basin were planted with a mixture of Coastal Bermuda grass (Cynodon dactylon L.) and Georgia 5 Fescue (Festuca arundinacea Schreb.). The watersheds have a slope ranging from 2 to 3.5% and the runoff contributing areas are defined by a soil berm. The experimental area consists of two different soils: the west side is a Esto sandy loam, while the east side is classified as an Orangeburg sandy loam. Both soils are fine-loamy, siliceous, thermic Typic Kandiudults. The subsurface watershed is defined by sandy clay loam layers containing plinthite starting at an approximate depth of 100 cm. These layers are slowly permeable and cause lateral flow above that depth. This layer is better developed under the Esto than under the Orangeburg. Watershed one (W1) was determined to be on the Esto, watershed three (W3) on the Orangeburg, and watershed two (W2) mainly on the Esto, but with one corner on the Orangeburg.

Tile drains installed at a depth of 120 cm with gravel to a depth of 50 cm at the upper hydrological boundaries divert incoming subsurface water. Drains installed at the lower hydrological boundaries catch the lateral subsurface flow. Runoff and subsurface flow are monitored using flumes and weirs. Samples are taken automatically on a flow weighted basis.

Two rates of poultry litter, 10 Mg ha^{-1} (1X) and 20 Mg ha^{-1} (2X), and a mix of poultry litter and composted poultry litter (C), 10 Mg and 50 Mg ha^{-1} (1X + C), are split applied in April and September. The 1X rate is the recommended application rate based on nitrogen requirements of a combination of Bermuda grass and fescue hay (200 kg ha^{-1}).

Runoff samples are analyzed for inorganic (NO_3 and NH_4) and total N, and total, bioavailable and soluble P. Subsurface samples are analyzed for inorganic N and soluble P. Soil samples were taken just before each application on a 10 x 10 m. grid at 6 depths (0-15, 15-30, 30-45, 45-60, 60-90, and 90-120 cm). Samples were analyzed for inorganic N (NO_3 and NH_4) and plant available P using an anionic resin extraction.

RESULTS AND DISCUSSION

First winter (1994-1995)

Data for the first winter (1994-1995), in which all watersheds received the same application of poultry litter (1X) , showed a different hydrological response among the watersheds. During the first winter the highest nitrate-N concentrations in the subsurface samples were 6.1, 4.3 and 1.1 mg L^{-1} and soluble P concentrations in the runoff samples reached maximum values of 4.9, 3.3, 1.2 mg L^{-1} for W1, W2 and W3, respectively. The differences between the watersheds are attributed to the two different soils. These data show that nitrate-N concentrations in subsurface flow under the 1X treatment did not exceed the U.S. Environmental Protection Agency drinking water standard of 10 mg L^{-1}. The soluble P levels are quite high considering recently established USEPA guidelines of 0.05 and 0.1 mg L^{-1} P for lakes and streams, respectively (Sharpley et al. 1996).

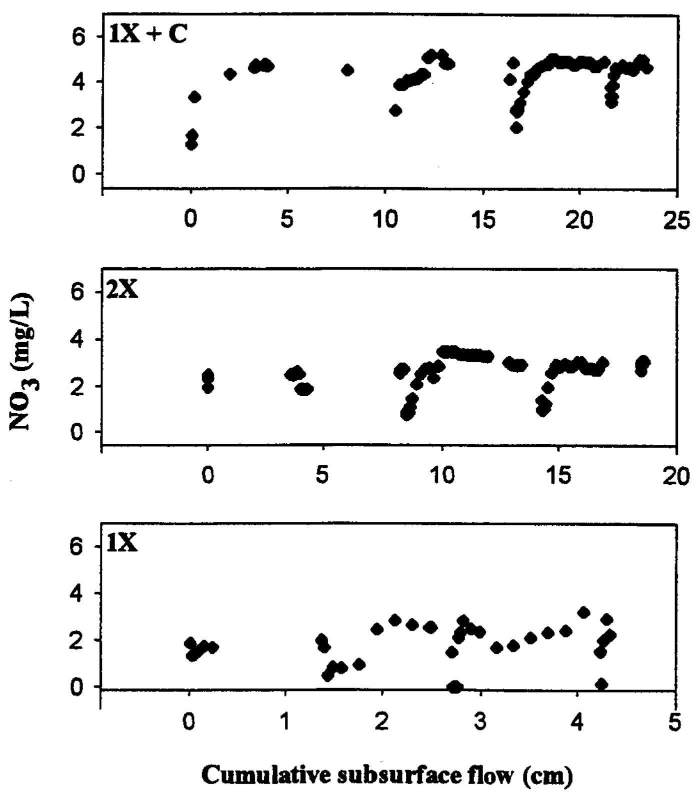

Figure 1. Nitrate-N concentrations in subsurface flow (March 1995 - March 1996).

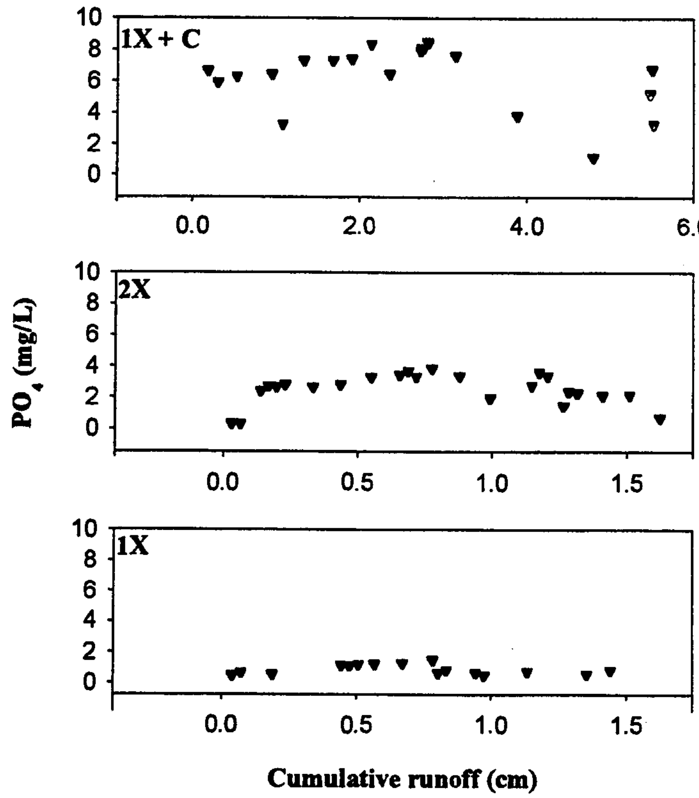

Figure 2. Soluble Phosphorus in runoff (March 1995 - March 1996).

Second year (1995-1996)

In the following year of variable treatment application, the summer was extremely dry and no significant runoff or subsurface flow occurred until after the second part of the split application was completed. Nitrate-N concentrations in subsurface flow, however, only reached 4.8, 3.5 and 2.9 mg L^{-1} as a maximum on the 1X + C (W1), 2X (W2) and the 1X (W3) treatments, respectively (Fig. 1). The generally lower concentrations could be explained by a much larger role of crop uptake in this year, due to a better developed forage. All concentrations remained under the drinking water standard even after addition of 400 kg ha^{-1} of total N with the compost.

Soluble P concentrations in the runoff reached 8.5, 3.8 and 1.6 mg L^{-1} on the 1X + C, 2X and the 1X treatments, respectively (Fig. 2). Here the addition of about 800 kg ha^{-1} of total P with the compost treatment increased the concentration of soluble phosphorus in the runoff under the 1X + C treatment.

Inorganic N levels in runoff were generally lower than 1 mg L^{-1}. Due to the timing of application first runoff events occurred well after application. At that time most of the inorganic N in the poultry litter was removed, transformed, immobilized or volatilized.

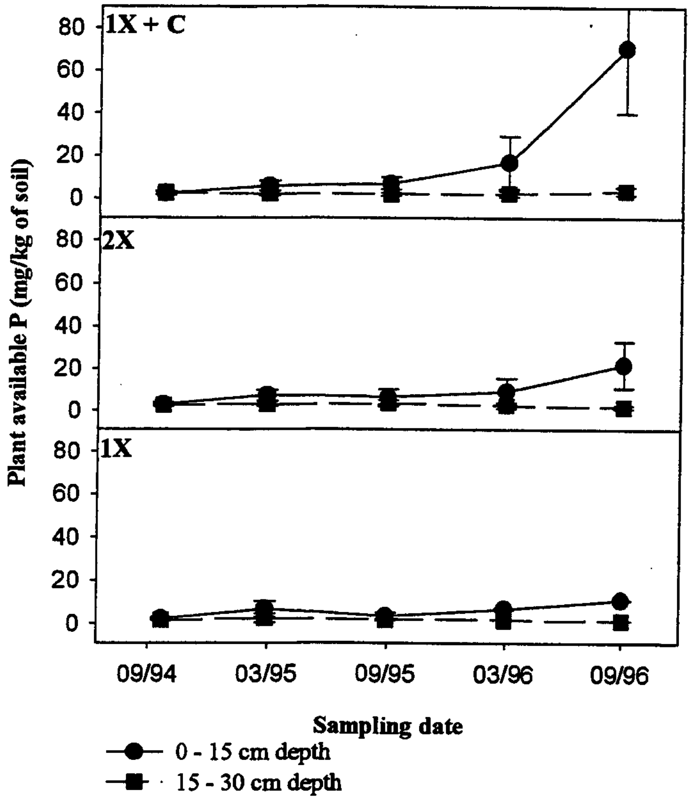

Figure 3. Plant available Phosphorus in soil (September 1994 - March 1996).

Plant available P in the upper 15 cm of the profile also increased, with the highest increase under the 1X + C (Fig. 3). Resin extractable P is about 30% of Mehlich III extractable P.

Research from the Netherlands indicates the possibility of saturating the soil with P, with the threat of P leaching to the groundwater or running of to surface water (de Haan & van der Zee, 1994). The degree of P accumulation is related to the so-called P sorption saturation index:

$$P\ sorption\ saturation = \frac{Extractable\ soil\ P}{P\ sorption\ maximum} x\ 100$$

In the Netherlands a P sorption saturation of 25% has been established as being the critical value above which the potential for P movement in surface and groundwater becomes unacceptable (Sharpley, 1995). Sharpley (1995) has shown that the P sorption saturation indices are also correlated with soluble P in runoff. On the three watersheds in this research the sorption saturation increased from 3.5, 5.8 and 2.3% in September 1994 to 83.2, 35.1 and 7.1% in September 1996 for the 1X + C, 2X and 1X treatment, respectively. The dramatic increase in sorption saturation here indicates a high potential for P runoff. The two watersheds which received more than the recommended rate have sorption saturation indices well above the Dutch limit, after only two years of application. Until this date however, no P has been observed in the subsurface flow.

Analysis of the runoff samples for total and bioavailable P levels showed that, for all treatments, the concentrations mainly consisted of soluble P. This is consistent with earlier results reported by Edwards and Daniel (1993).

All of the P concentrations in the runoff are lower than earlier reported values (Kaheel et al. 1980, Shreve et al. 1995) which were found in small plot runoff studies. This is probably due to differences in scale (small plot vs. field scale) and timing of rainfall (natural vs. simulated).

Total amounts of N and P lost in runoff and subsurface flow were relatively low. Total N lost in surface and subsurface flow in the second year (1995-1996) was 5.8, 2.4 and 0.7 kg and total P lost was 2.4, 0.3 and 0.1 kg for the 1X + C, 2X and 1X treatment, respectively. This is due to the few runoff and subsurface flow events which occur on these soils.

CONCLUSIONS

These results, in general, show that composting works well in reducing the amount of N being lost, but does not reduce the amount of P. Since most of the P is soluble, the data also suggest that conventional measures, like filter strips and riparian zones, will not lower the concentration in the runoff substantially. Only increasing plant uptake, or stabilizing the P in litter with the use of additives, like alum (Shreve et al, 1995), could decrease these concentrations. These soils have only a few runoff events occurring each year, and generally in winter, but concentrations in each event are high and still a threat to water quality in the area. Application of P above crop use results in a build up of P in soil, which could lead to water quality problems at a later point in time. These results also reconfirm the importance of studies at the field scale under natural conditions if guidelines for application of animal wastes are to be developed.

ACKNOWLEDGMENTS

This research was supported in part by funds from the CSREES water quality research program competitive grants/USDA, grant # 92-34214-7354 and the Southeastern Poultry & Egg Association, project # 131

LITERATURE CITED

Edwards, D.R. and T.C. Daniel. 1993. Effects of poultry litter application rate and rainfall intensity on quality of runoff from fescue grass plots. *J. Environ. Qual. 22:361-365.*

Georgia Agricultural Statistics Service, 1994. *Georgia Agricultural facts.*

Haan, F.A.M. de, and S.E.A.T.M. van der Zee, 1994. Soil Protection and Intensive Animal Husbandry in the Netherlands. *Marine Pollution Bulletin Vol 29: 439-443.*

Khaleel, R. K.R. Reddy and M.R. Overcash, 1980. Transport of potential pollutants in runoff water from land areas receiving animal wastes: a review. *Water Research 14: 421:436.*

Perkins, H.F., M.B. Parker, and M.L. Walker. 1964. Chicken Manure - its production, composition and use as a fertilizer, *Bull. NS 123 Georgia Agricultural Experiment Station, Athens,GA.*

Sharpley, A. N. 1995. Dependence of runoff phosphorus on extractable soil phosphorus. *J. Environ. Qual. 24:920-926.*

Sharpley, A., T.C. Daniel, J.T. Sims, and D.H. Pote. 1996. Determining environmentally sound soil phosphorus levels. *J. Soil and Water Cons. 51(2): 160 - 166.*

Shreve, B.R., P.A. Moore, Jr., T.C. Daniel, D.R. Edwards and D.M. Miller, 1995. Reduction of phosphorus in runoff from field applied poultry litter using chemical amendments. *J. Environ. Qual. 24:106-111.*